State of California
The Resources Agency
Department of Water Resources

INTERIM REPORT ON PRE-SPAWNING CHINOOK SALMON MIGRATION PATTERNS AND HOLDING CHARACTERISTICS SP-F10 TASK 1E

Oroville Facilities Relicensing
FERC Project No. 2100

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REPORT SUMMARY

Task 1E evaluates water temperatures, depth and migration patterns of pre-spawning adult Chinook salmon in the Feather River below the Fish Barrier Dam. Adult Chinook salmon were captured and tagged with radiotelemetry and archival tags. Of the 18 fish tagged, 16 were subsequently relocated. Of these sixteen, six were harvested by fishermen, and three entered the hatchery. While the fate of the remaining seven fish is uncertain, at least five of these appeared to have died in the vicinity of spawning grounds in the low flow channel.

Water temperatures used by pre-spawning adult Chinook salmon in the Feather River were compared to a recommended migration temperature (16°C) and an estimated maximum water temperature (20°C) to determine the frequency with which temperature recommendations were exceeded. Water temperatures ranged from 12.8-20.8°C but most observations occurred between water temperatures of 16 and 20°C. Water depth use was compared to the hypothesis that holding habitat occurs in water greater than two meters. However, tag malfunction left only three tags with archival depth data. Among these three tags, fish spent the greatest amount of time at depths between two and ten meters Based on these observations, suitable depths and water temperatures do not appear to be lacking in the portion of the Feather River utilized by tagged Chinook salmon.

Radiotelemetry data were used to determine what sections of the river were used for holding and the effect of artificial structures, such as the Thermalito Afterbay Outlet, on migration. The majority of fish exhibited upstream movement with only one fish remaining downstream of Marysville/Yuba City. Over 90% of the final fish locations and assumed areas of spawning occurred upstream of Gridley. Fish were most often located around the Thermalito Outlet or Robinson Riffle (the temperature compliance point). Thermalito Outlet appeared to be a factor in the migration of Chinook salmon. Four tagged fish were harvested at Thermalito Outlet and another three fish spent at least 19 days holding in the area.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Adult migrating Feather River Chinook salmon were captured and tagged to assess preferences regarding holding habitat, water temperature and depth.

1.1 BACKGROUND INFORMATION

Adult Chinook salmon exhibiting spring-run life history migrate upstream beginning in March and continue through July (NMFS 2001). When these adult Chinook salmon enter freshwater, they are sexually immature and their gonads mature during the summer holding period (DWR and USBR 2000). Chinook salmon with spring-run life-history hold in their natal tributaries for up to several months in deep coldwater pools, usually greater than two meters, before spawning occurs (NMFS 2001; Moyle 2002). These salmon usually does not hold in the same pool all summer but rather exhibit upstream movement between pools (Moyle 2002). In the Feather River, most pre-spawning adult Chinook salmon typically hold in the upper 3 miles of the Feather River below the Fish Barrier Dam (D. Painter, pers. com. as cited in DWR and USBR 2000), where water temperatures are cooler than downstream (DWR and USBR 2000). Torgersen et al. (1999) cited 16°C as the thermal optima for migrating spring-run Chinook in the John Day River, Oregon. The estimated maximum thermal limit for pre-spawning adults falls around 20°C (Marine 1992; NOAA Fisheries 1997).

Because Thermalito Afterbay releases cause warmer water temperatures downstream, the most suitable holding habitats are likely upstream of the Thermalito Afterbay outlet (DWR and USBR 2000). A water temperature modeling effort was conducted on the Feather River for DWR and USBR's Biological Assessment of the effects of the Central Valley Project and State Water Project on Chinook salmon exhibiting spring-run life-history. It concluded that for 2000 and 2001, it was unlikely that adult Chinook would use the portion of the Feather River below the Thermalito Afterbay outlet except as a migration corridor to the upper reaches of the river (DWR and USBR 2000). However, fieldwork is necessary to determine whether or not the pools downstream of the Thermalito Afterbay Outlet provide water temperatures suitable for holding adult Chinook salmon.

1.1.1 Statutory/Regulatory Requirements

Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects, including a discussion of the fish, wildlife and botanical resources in the vicinity of the project. The discussion needs to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact for on-going and future operations. This report fulfills these requirements, by evaluating potential project effects on migrating Chinook salmon and their habitat in the Feather River below the Fish Barrier Dam.

1.1.2 Study Area

The upstream extent of the telemetry study was the Fish Barrier Dam and the downstream extent was the confluence of the Feather and Sacramento Rivers.

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam, creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating

Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

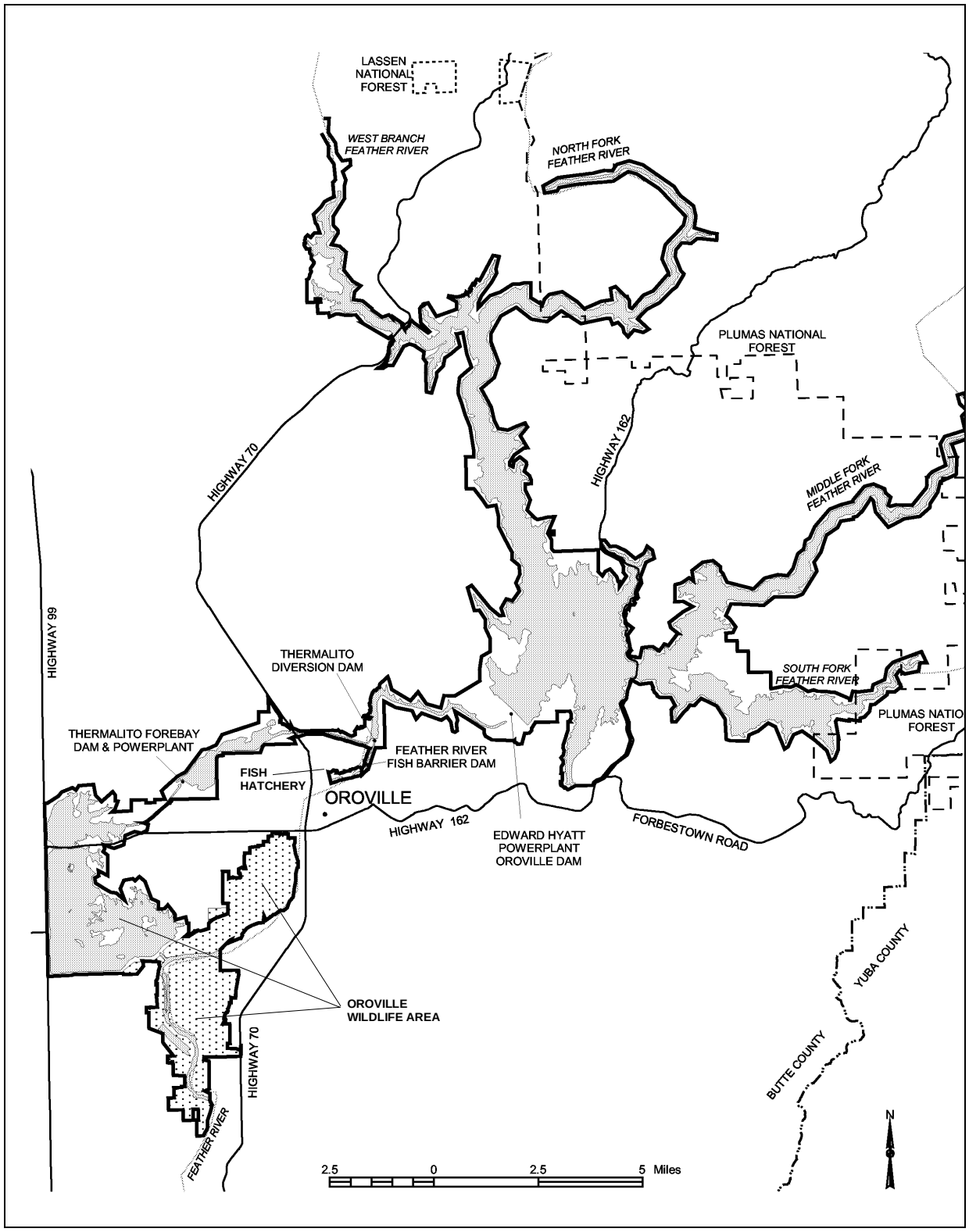


Figure 1.2-1. Oroville Facilities FERC Project Boundary

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements are greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, “Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife,” sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the

Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice

water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the

watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

Insufficient field data exists to corroborate assumptions regarding Chinook salmon migration timing and holding habitat use in the Feather River. Reasons for this include a lack of a permanently established migration monitoring program, such as annual operation of a counting weir. In addition, there is no geographic segregation of early arriving and later arriving adult Chinook. Therefore, arrival time cannot be distinguished in the field by observation because it is not possible to tell whether an adult has been holding for days (fall-run life-history) or months (spring-run life-history) prior to spawning. Little is known about where pre-spawning Chinook salmon adults hold in the Feather River. The water temperature regime associated with the ongoing operation of the Oroville facilities may expose pre-spawning adult Chinook salmon to elevated water temperatures during the migration and holding period, which may adversely impact reproductive success. This study was conducted to collect data to evaluate water temperature, depth, and migration patterns of pre-spawning adult Chinook salmon in the Feather River below the Fish Barrier Dam.

3.0 STUDY OBJECTIVE(S)

Task 1E evaluates Feather River water temperatures, depth and migration patterns of pre-spawning adult Chinook salmon. Operation of the Oroville Facilities affects the water temperature regime in the Feather River below the Fish Barrier Dam. Water temperature is an important factor influencing adult Chinook salmon upstream migration and spawning success. Water temperatures may provide attraction cues and influence pre-spawning adult survival and egg viability. Task 1E is broken into two objectives.

Objective 1: Analyze archival data in order to compare pre-spawning Chinook salmon (a) water temperature use with recommended pre-spawning temperatures, and (b) depth profiles with recommended holding habitat depths.

Objective 2: Analyze tracking data for adult Chinook salmon migration patterns.

4.0 METHODOLOGY

4.1 STUDY DESIGN

In order to assess migration patterns and holding habitat, 18 adult Chinook salmon were captured and tagged with radiotelemetry and archival tags to document their habitat use. Fish movements were monitored using a combination of manual tracking and fixed data logging stations. Water temperature and pressure data were logged using archival tags. Unlike radiotelemetry tags, information from archival tags can not be retrieved remotely: the tags must be retrieved (i.e. from anglers, hatchery, or from spawned carcasses) in order to recover the stored depth and temperature data.

The original radiotelemetry study design called for as many as thirty Chinook salmon to be tagged in late spring. However, onset of the study was delayed until late July due to complications with research permits and equipment acquisition. The late start made capture of early-migrant Chinook salmon at the confluence of the Yuba River unlikely, so fish capture efforts focused around the Gridley area.

4.2 HOW AND WHERE THE STUDIES WERE CONDUCTED

Beginning in July, adult Chinook salmon were captured by angling at River Mile (RM) 53.6 in the Feather River. Angling began July 9 and continued every week until August 8, 2003 (Table 4.2-1). A total of 421 angler hours were accumulated in this effort. All angling efforts were guided by Craig Smith of Craig Smith Fishing Guide Service.

Table 4.2-1. Date and angling effort for 2003 Chinook salmon telemetry study.

Angling date	Angler hours
9-Jul	49
15-Jul	21
17-Jul	21
22-Jul	21
24-Jul	21
28-Jul	32
29-Jul	32
30-Jul	32
31-Jul	24
1-Aug	24
4-Aug	32
5-Aug	32
6-Aug	32
7-Aug	32
8-Aug	16
Total hours	421

In all, 18 adult Chinook salmon received an esophageal implant of a shrink-wrapped combination radiotag and water temperature/pressure sensor archival tag (Table 4.2-2). Tagged fish were immediately released in the vicinity of their capture. Roughly 65% of the fish tagged were females.

Table 4.2-2. Summary information on Chinook salmon captured for the 2003 telemetry study. Grey rows indicate tagged fish that were never relocated after release.

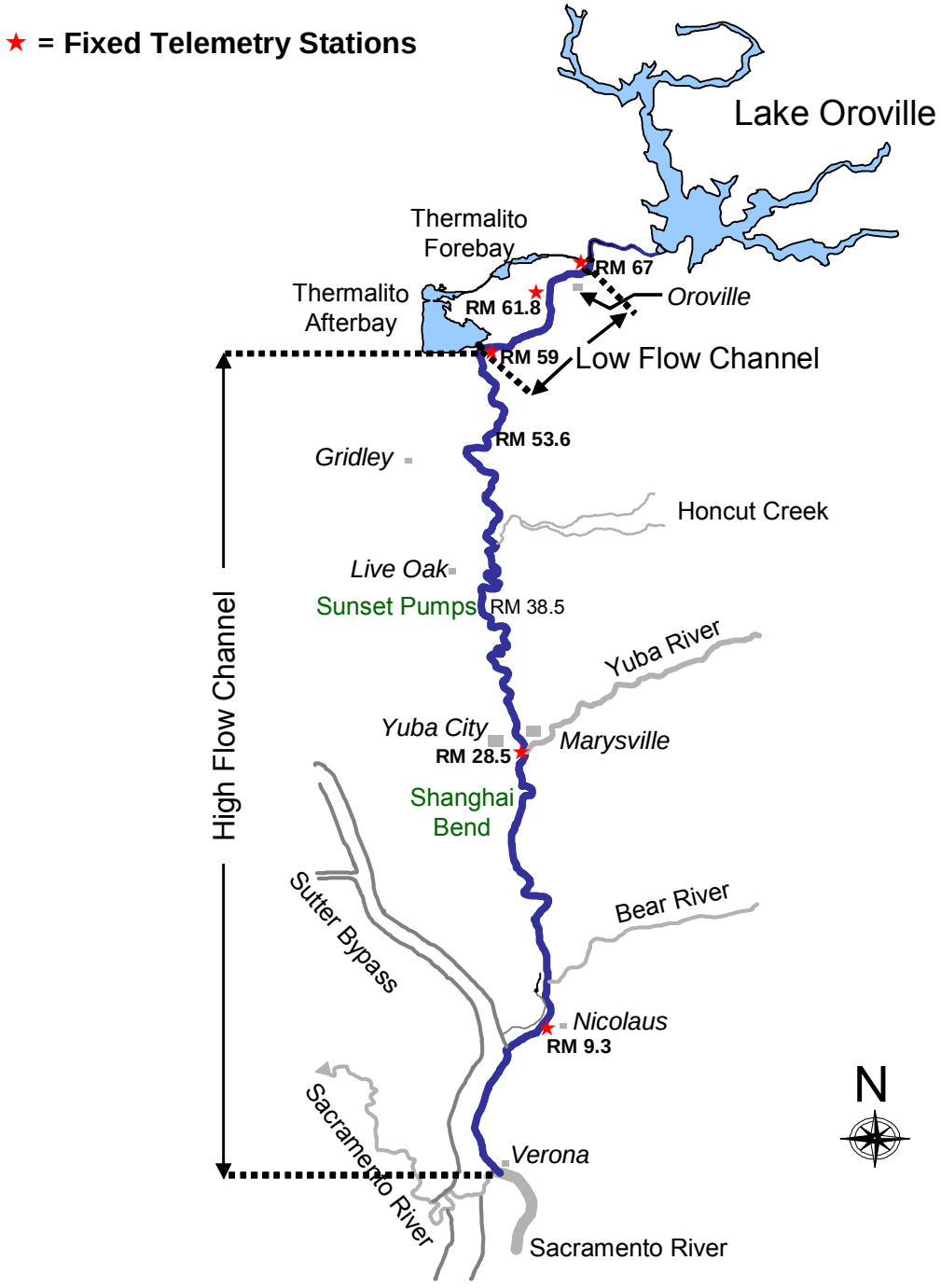
Fish #	Tag Date	Release Time	Release Location	River Mile	Tag Code	FL	Sex	Recovery Date	Recovery Location	Tag returned
1	7/9/03	1100	Yuba City	28.5	76	710	N/A			
2	7/30/03	610	Big Riffle	53.6	78	940	M	9/8/03†	Outlet	No
3	7/30/03	640	Big Riffle	53.6	81	940	F	10/2/03	Hatchery	Yes
4	7/30/03	750	Big Riffle	53.6	84	820	F			
5	7/30/03	900	Big Riffle	53.6	79	900	F	8/18/03	Outlet	Yes
6	8/1/03	745	Big Riffle	53.6	68	760	F			
7	8/1/03	925	Big Riffle	53.6	54	860	F	8/17/03	Outlet	Yes
8	8/1/03	1020	Big Riffle	53.6	88	720	F	9/8/03	Hatchery	Yes
9	8/1/03	1105	Big Riffle	53.6	87	880	M	8/14/03	LFC	Yes
10	8/4/03	550	Big Riffle	53.6	86	920	F			
11	8/4/03	645	Big Riffle	53.6	50	880	F			
12	8/4/03	730	Big Riffle	53.6	83	840	M			
13	8/4/03	850	Big Riffle	53.6	52	870	M	8/9/03	Outlet	No
14	8/4/03	1000	Big Riffle	53.6	72	810	M	10/1/03	Hatchery	Yes
15	8/6/03	710	Big Riffle	53.6	56	860	M			
16	8/6/03	735	Big Riffle	53.6	62	790	F			
17	8/7/03	735	Big Riffle	53.6	82	780	F	8/24/03	unknown	Yes
18	8/7/03	825	Big Riffle	53.6	69	860	F			

† Fixed station data indicates this fish was in the system after the recapture date. Tag number may have been misidentified by angler- unable to verify.

Manual tracking by boat occurred at one to two weeks intervals from July 18, 2003 until January 8, 2004 except for October when all personnel were required to assist with the adult escapement survey and tracking was not conducted. Manual tracking by plane occurred weekly from July 18 - August 26, 2003 (there was no August 19 flight). Flights were used to cover a larger search area to determine if some of the tagged fish that could not be located had moved into the Yuba River or the Sacramento River below the confluence with the Feather River.

Figure 4.2-1 shows the locations of the fixed stations at the Feather River Hatchery (RM 67) and within gauging stations located at Robinson (RM 61.8), the Thermalito Afterbay Outlet (RM 59), the Yuba City/Marysville Bridge (RM 28.5) and Nicolaus (RM 9.3). Location considerations for fixed station receivers included areas that exhibited potential holding habitat and/or limited access to protect against equipment vandalism.

Figure 4.2-1. Pre-spawning Chinook salmon telemetry study site showing fixed station locations and corresponding river mile (RM). Angling for Chinook salmon took place at RM 53.6.



Pressure measurements (PSI) obtained from the archival tags were converted to depth using the following equation from Harris 2000:

$$\text{m of } H_2O = \frac{\text{PSI} \times 6894.757 \text{ Pa/PSI}}{9.80069 \times \rho}$$

where ρ = density of water as a function of water temperature.

5.0 STUDY RESULTS

Of the 18 combo-tags deployed, 16 were subsequently relocated. Of these sixteen, six were harvested by fishermen and three entered the hatchery. The fate of the remaining seven fish is uncertain. Five non-moving signals were detected in spawning areas, but these tags were not found among any of the reachable salmon carcasses. Two of these signals originating in a deep pool at Upper Robinson, and another signal at the Thermalito Outlet was too deep for carcass retrieval. Two additional signals may have come from regurgitated tags or ones that fell out of decomposed fish. These tags may have been buried in the substrate as the signals were traced to searchable areas but carcasses retrieved did not contain any of the tags. The fate of the two remaining fish is uncertain. Tag 57 was last detected at RM 57 on August 18 and may have been harvested. Tag 84 was last detected at RM 9.3 on September 3 and may have left the system. Of the three fish recovered from the Feather River Fish Hatchery two were spawned (Tag 72 and 81) and one died before it could be spawned (Tag 88). Depth and temperature data were downloaded upon retrieval of the seven tags recovered from anglers and the Feather River Hatchery.

5.1 MIGRATING/HOLDING CHARACTERISTICS

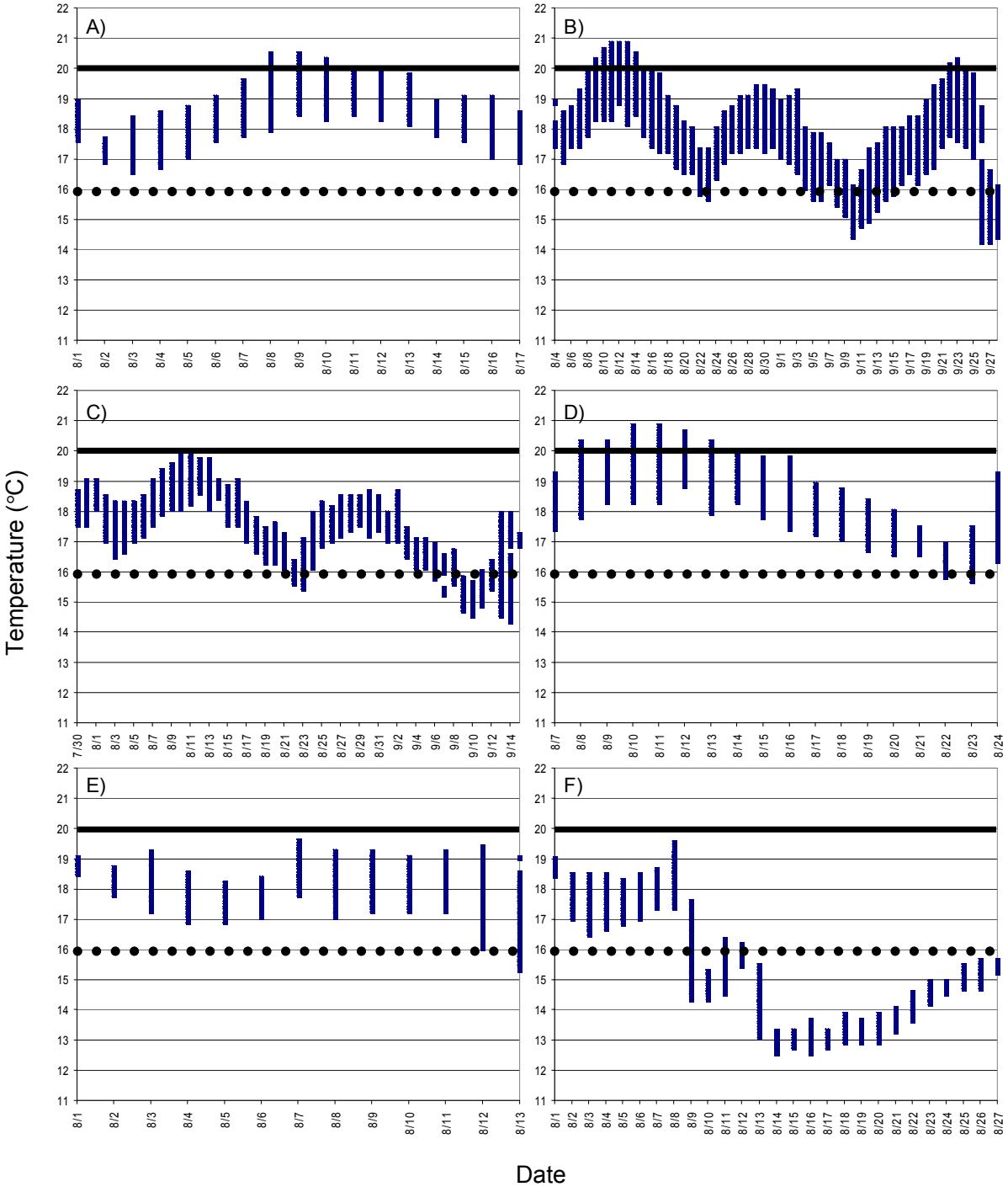
5.1.1 Water Temperature

As part of the first objective, water temperatures used by pre-spawning adult Chinook salmon in the Feather River were compared to a recommended migration temperature (16°C) and an estimated maximum water temperature (20°C) to determine the frequency with which temperature recommendations were exceeded. During analysis, the data from Tag 79 were deemed unreliable (e.g., temperatures below 9°C were recorded on August 14) and was excluded from analysis. Tagged Chinook salmon traveled in waters between the temperatures of 12.8-20.8°C (Figure 5.1.1-1). Five of the six fish typically frequented waters between the recommended migration temperature and upper water temperature while fish Tag 88 regularly utilized water below the recommended migration temperature (Table 5.1.1-1). Three of the fish were recorded from 3-8% of the time above the maximum water temperature (Table 5.1.1-1)

Table 5.1.1-1. Frequency of water temperature use of individual Chinook salmon in the lower Feather River during the 2003 telemetry study.

Temperature °C	Tag 54	Tag 72	Tag 81	Tag 82	Tag 87	Tag 88
< 16	0.0%	12.2%	10.6%	2.4%	1.2%	67.2%
≥16 and < 20	95.0%	84.9%	89.4%	89.5%	98.8%	32.8%
≥ 20	5.0%	2.9%	0.0%	8.1%	0.0%	0.0%

Figure 5.1.1-1. Temperature profiles of individual Chinook salmon A) Tag 54, B) Tag 72, C) Tag 81, D) Tag 82, E) Tag 87, and F) Tag 88 in the lower Feather River during the 2003 telemetry study. The upper solid line represents an estimated maximum thermal limit and the lower dotted line represents the suggested migration temperature.



5.1.2 Depth

As part of the first objective, water depth utilized was compared to the hypothesis that holding habitat occurs in water greater than two meters. Only three tags were analyzed as four of the seven pressure sensors were defective. Fish spent the greatest amount of time at depths between two and ten meters (Table 5.1-2). One Chinook salmon, Tag 81, spent over 15% of its time in water deeper than 10 m (Table 5.1-2). Eighty-three hours was the longest period of time that this fish held at a depth of approximately 10 m.

Table 5.1.2-1. Frequency of time Chinook salmon spent at varying holding depths during the 2003 telemetry study.

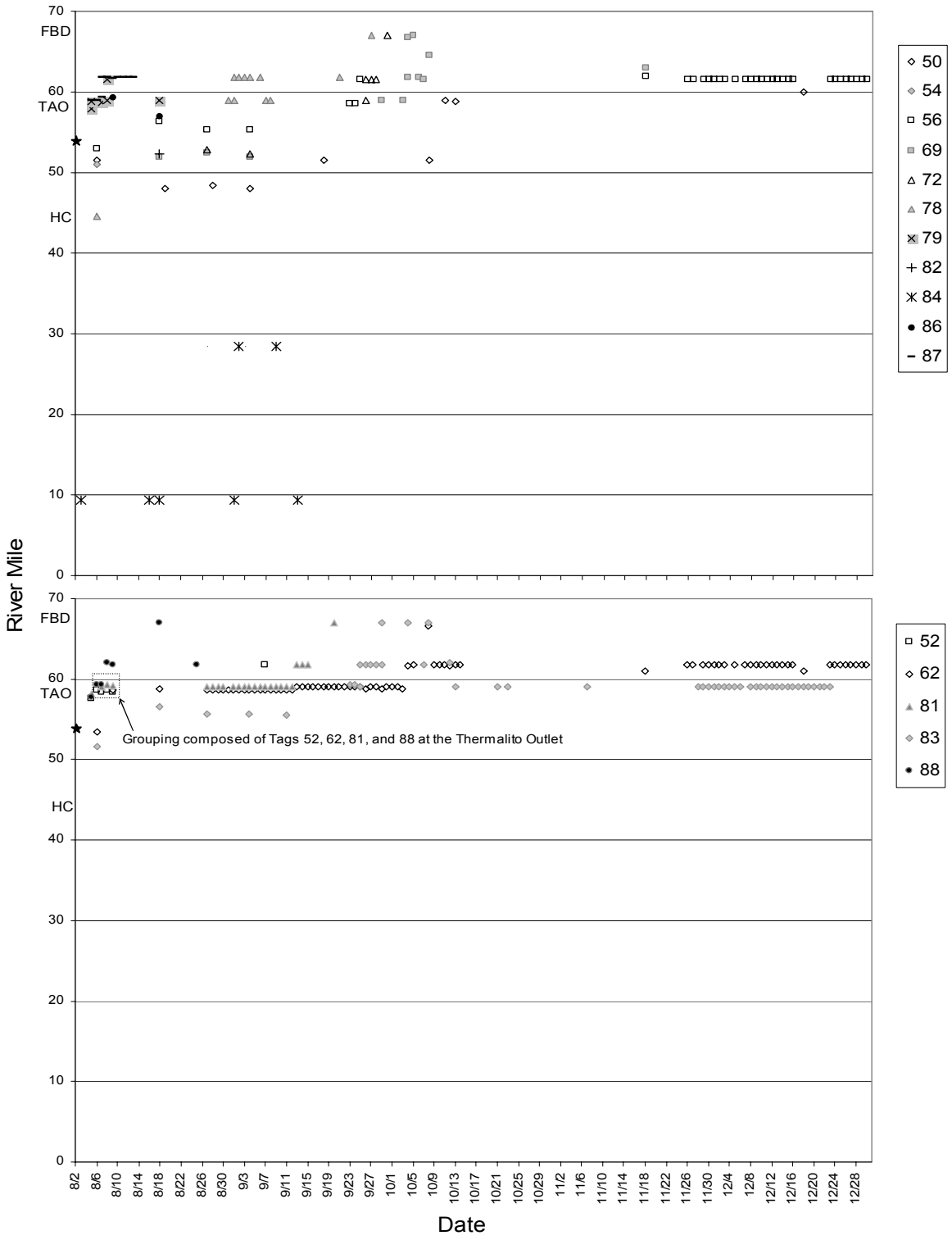
Depth (m)	Tag 72	Tag 81	Tag 87
≤ 2	6.4%	3.9%	30.7%
> 2 and ≤ 5	43.4%	28.3%	66.1%
> 5 and ≤ 10	50.1%	52.4%	3.2%
> 10	0.0%	15.4%	0.0%

Appendix A displays temperature and depth graphs received from NOAA Fisheries of a Chinook salmon that they tagged in Half Moon Bay, California on July 25, 2003. This fish was recovered upstream of RM 63 during the carcass survey on November 4, 2003.

5.2 MIGRATION PATTERNS

To fulfill the second objective, movement of adult Chinook migrants was analyzed for holding habitat use patterns. Radiotelemetry data were used to determine what sections of the river were used for holding, the length of time spent holding in each section of river, and the effect of artificial structures such as the Thermalito Afterbay Outlet (RM 59) on migration behavior. The movement patterns of each tagged Chinook salmon are displayed by date and detected location in Figure 5.2-1.

Figure 5.2-1. Movement of individual adult Chinook salmon in the lower Feather River during the 2003 telemetry study. Two graphs are used to help separate fish for easier viewing. Note: star = release location of tagged fish, FBD = Fish Barrier Dam, TAO = Thermalito Afterbay Outlet, and HC = Honcut Creek. Fixed receiving stations were located at RM 9.3, 28.5, 59, 61.8, and 67.



Of the 18 fish tagged, 16 were relocated at least once. Fish were at liberty or detected anywhere from 5-146 days after being tagged (Table 5.2-1). Ten fish exhibited variable upstream/downstream movement, one fish only downstream movement, and the other five only upstream movement (Table 5.2-1). The total distance moved by tagged Chinook salmon ranged from 5.4 to 82.7 RM. The largest observed net movement was 44.3 RM, which was navigated downstream by fish Tag 84 (Table 5.2-1). Swim rates ranged from 0.1-1.84 RM/day (Table 5.2-1). The Thermalito Outlet appeared to have an impact on the migration behavior and fate of tagged salmon. Of the sixteen fish successfully tracked, seven fish either spent at least 19 days or were harvested at the Thermalito Outlet (Table 5.2-1).

Table 5.2-1. Summary of migration patterns for individual Chinook salmon during the 2003 telemetry study. Note : * information not available as fish was not relocated after tagging. (H) indicates fish that were known to be harvested by anglers at Thermalito Outlet.

Tag #	At Large†	Total (RM)	Net (RM)	Last Location (RM), date	Rate (RM/day)	Days at 59††
50	136	21.6	12	60, Dec. 18	0.16	2
52	5	5.4	5.4	59, Aug. 9	1.08	4 (H)
54	16	10.6	8	59, Aug. 17	0.66	1 (H)
56	146	11.6	8.8	61.8, Dec. 30	0.10	2
62	139	21.2	13.5	61.8, Dec. 30	0.15	42
68	*	*	*	*	*	*
69	103	26.6	14.8	63, Nov. 18	0.26	2
72	55	11	9.6	61.8, Oct. 1	0.20	1
76	*	*	*	*	*	*
78	59	38.2	22.5	67, Sept. 27	0.65	4 (H)
79	19	13.2	8.2	59, Aug. 18	0.69	4 (H)
81	52	13.4	13.4	67, Oct. 2	0.26	19
82	11	1.4	1.4	52.2, Aug. 24	0.13	0
83	141	38.2	15.5	59, Dec. 23	0.27	33
84	45	82.7	44.3	9.3, Sept. 13	1.84	0
86	14	7.4	5.4	57, Aug. 18	0.53	1
87	12	8.2	8.2	61.8, Aug. 14	0.68	4
88	24	13.4	13.4	67, Sept.8	0.56	2

† At large equals the amount of days between date of being tagged and date of recapture/last detection
†† Days at 59 equals the total number of nonconsecutive days the fish was detected at the Thermalito Afterbay Outlet while at liberty

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

6.1.1 Holding/Migration Characteristics

Fish Tags 88 and 1051 (recovered NOAA Fisheries tagged Chinook salmon) data indicate that cooler water temperatures, as low as approximately 12°C, were available. The spawning success of fish Tag 1051 was not determined in the field because the fish was male. Fish Tag 88 spent the most amount of the time in water below the recommended migration temperature prior to entering the hatchery but died before being spawned. This may be due to the fish experiencing more drastic temperature changes (e.g., 19.5°C on August 8 dropping to around 14.5°C on August 9) in comparison to the other tagged fish (i.e., experienced a 3°C difference) or by other unknown factors. However, most of the temperature logger data from tagged adult Chinook salmon fell between the recommended migration temperature and the estimated maximum water temperature. Since the spawning success of all the tagged fish except those two spawned at the FRH is unknown, it is not possible to draw any substantive conclusions regarding temperature impacts on spawning success.

The depth data retrieved indicates that pre-spawning Chinook salmon do not have difficulties finding pools >2-m to hold in. The two fish that spawned spent more than 50% of their time in pools >5-m deep which may suggest that Chinook salmon are more likely to survive in deeper holding areas. However, the fact that depth data was available from only three fish makes this a very uncertain and speculative interpretation.

6.1.2 Migration Patterns

Burger et al. (1985) and Bernard et al. (1999) have shown that tagged adult Chinook salmon have a tendency to head downstream after release and then may resume upstream migration. Approximately 50% of the relocated Chinook salmon tagged in this study moved and/or remained downstream for a period ranging from a few days to over two months. Fish Tag 82 remained downstream between Nicolas and Yuba City throughout the study period. The majority (>90%) of final fish detection locations and assumed spawning occurred above RM 52 (Gridley). Three out of 16 fish stayed for more than 19 days at the Thermalito Outlet which is comparable to two fish at Robinson. However, at least four tagged fish were harvested at Thermalito Outlet. If these fish were not harvested, they may have resided at Thermalito Outlet for an extended period. It is unclear at this time if the Outlet and Robinson are preferred holding locations or whether longer holding periods are suggested because of the fixed stations located at both areas.

6.2 PROJECT RELATED EFFECTS

Based on the data evaluated in this study, it appears that pre-spawning Chinook salmon prefer to utilize water temperatures between 16-20°C. The suggested temperatures and depths are presently available in the lower Feather River under existing flow and temperature regimes. However, completion of SP-W6 will provide further insight into the water temperatures available to migrating Chinook salmon downstream of the Fish Barrier Dam. SP-W6 will help determine if the temperatures utilized by migrating Chinook throughout the period of the telemetry study were preferred (i.e. selected) or if they were subject to what was available. Thermalito Afterbay Outlet appears to be a factor in the migration of Chinook salmon, if only because it attracts such intense fishing pressure. Further data collected from the 2004 radiotagging survey will help support development of water temperature and pool depth use profiles for early-migrant adult Chinook salmon. The use profiles will then allow estimation of the factors that are important for holding habitat. This will allow an estimation of the potential effects of continued operations and various operational scenarios that may change water temperature or pool depth.

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APPENDICES

APPENDIX A

TEMPERATURE AND DEPTH GRAPHS OF A CHINOOK SALMON TAGGED BY NOAA FISHERIES AND RECOVERED IN THE 2003 CARCASS SURVEY

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Summary of tag # 1051
Chinook (*O. tshawytscha*)

	Deployed	Recovered
Date	25 July 2003	4 November 2003
Time	09:43	--- found dead ---
Where	Lat: 37.89°N Long: 122.97°W Half Moon Bay, CA	Lat: 39.48 ° N Long: 121.58° W Oroville, CA *Feather River*
Length	78 cm (30.7 in)	*~ 84 cm (33 in)*
Weight	---	---

1051